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(54) **Electromagnetic injectors and methods for making same**

(57) An electromagnetic injector comprises a hollow body in three parts 1, 5, 7, assembled by a crimping envelope 9, a coil 10, an endpiece 14, and an injection needle 11 terminating in a tip 12 which abuts on a convergent seating 2. The needle 11 slides in a guide ring 31 having longitudinal groove 29. The seating 2 is obtained by die-stamping. Machining of the stop 18 against which the pole face 13 on the needle 11 abuts is effected with high precision. One application of the present invention is the mass-production of injectors intended for the direct or indirect electronic injection of fuel in a heat engine. The method of assembly and adjustment of a return spring 20 are described.

FIG.1

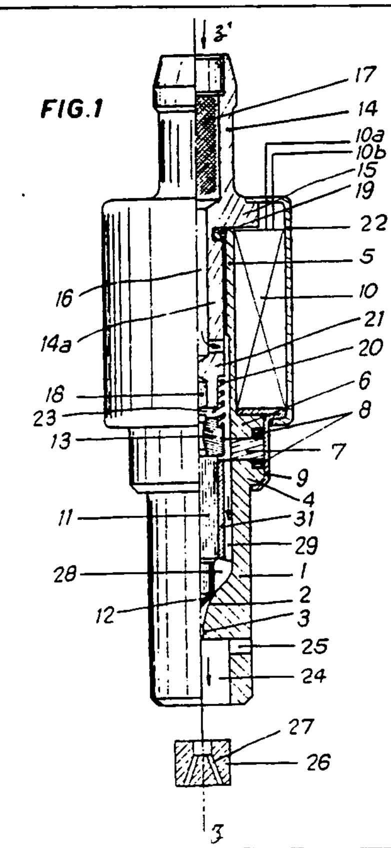

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FIG.1

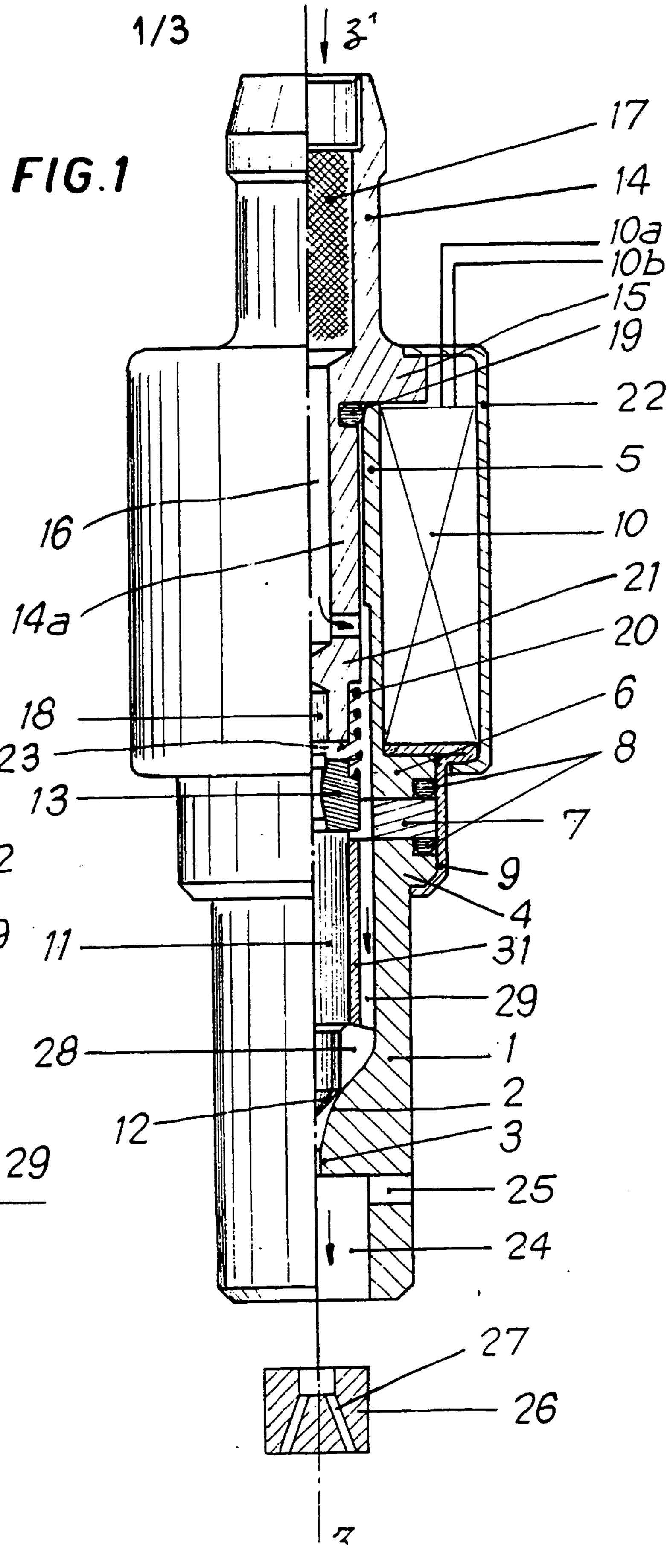
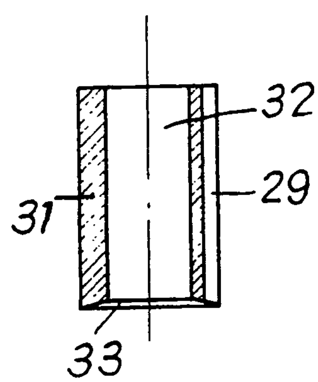


FIG.2



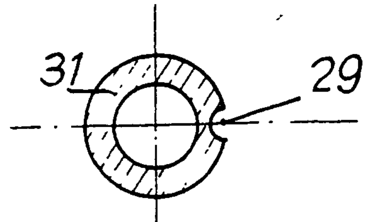


FIG.3

FIG. 4

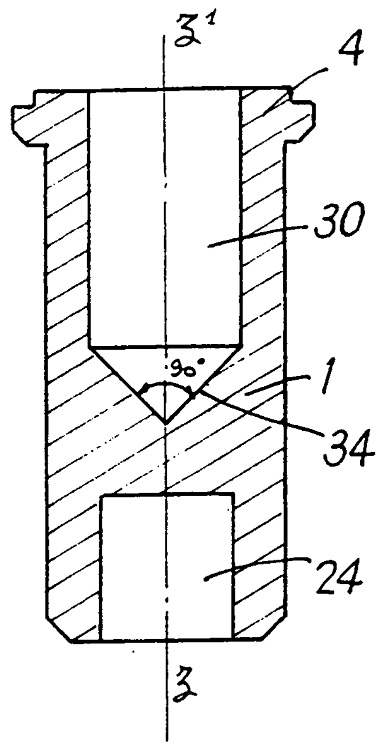
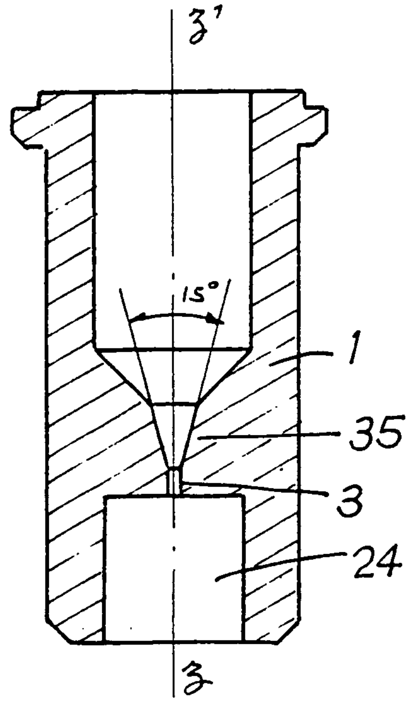


FIG. 5



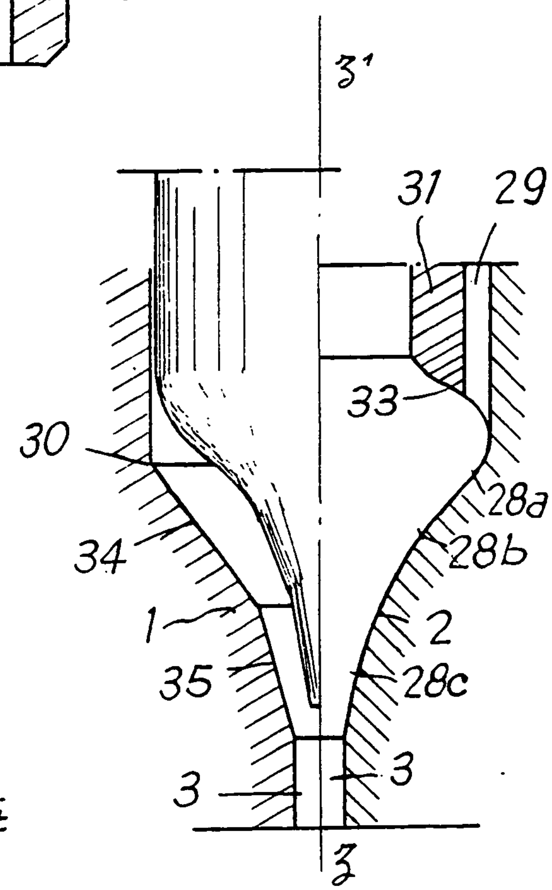


FIG. 6

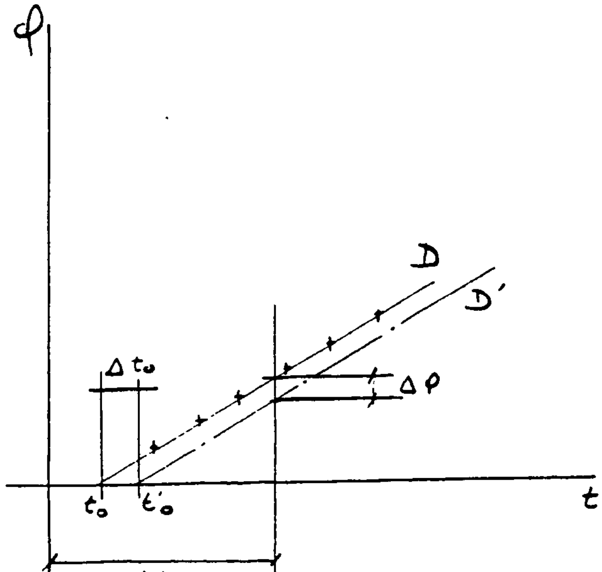


FIG. 7

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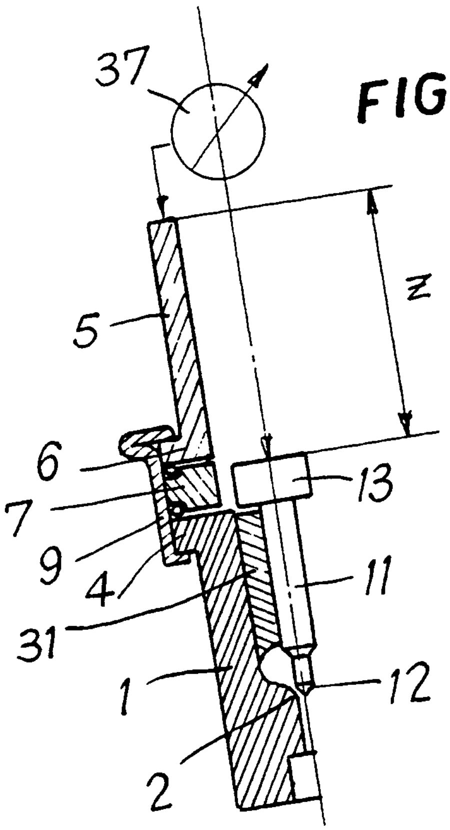

FIG.8

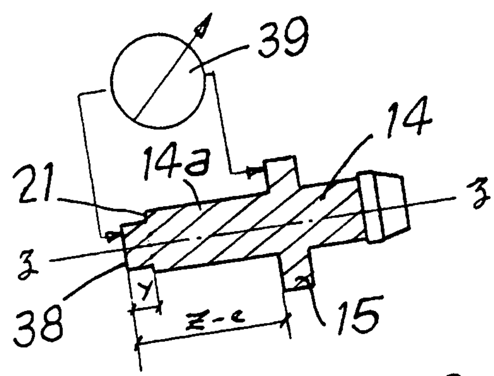

FIG.9

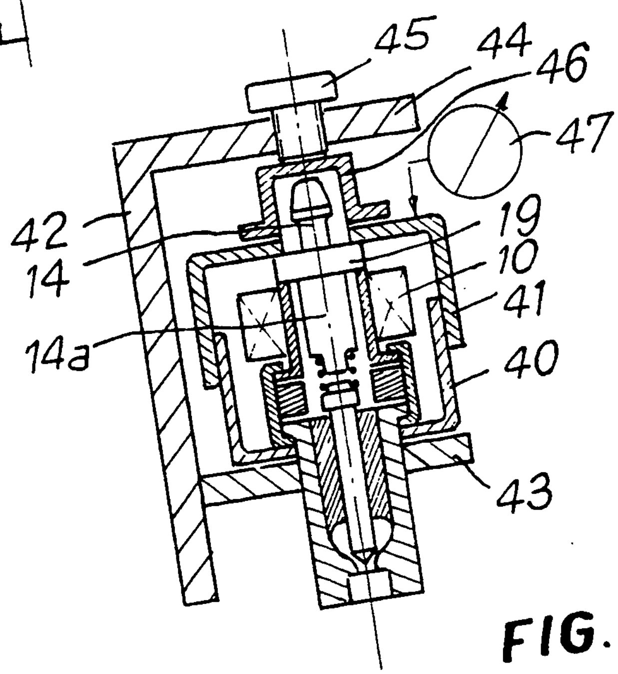

FIG.10

SPECIFICATION

Electromagnetic injectors and methods for making same

The present invention relates to new electromagnetic injectors and to methods for making same.

The technical sector of the invention is that of the manufacture of electromagnetic injectors, particularly injectors intended for the direct or indirect electronic injection of petrol, or gasoline, or of another combustible fluid in a heat engine.

Devices for electronically injecting petrol are already known which comprise, on the one hand, an electromagnetic injector provided with a coil and a valve with needle and, on the other hand, means for sending to the coil of this injector square voltage pulses.

To vary the quantity of petrol injected, the duration of the pulses is varied and electronic means monitor this duration with very high precision, greater than one thousandth of a second.

On the contrary, heretofore known methods for manufacturing electromagnetic injectors do not enable batches of injectors to be mass-produced economically whose rates of flow are uniform with a maximum variation of ±1% for all the injectors of the same batch.

The quantity of petrol Q distributed by an electromagnetic injector with needle during a pulse of determined duration Δt is of the form $Q = dQ/(dt).(\Delta t - to)$.

This quantity therefore essentially depends on two factors dQ dt and to. The first factor dQ/dt is substantially constant, so that the quantity Q varies proportionally to Δt along a straight line.

The factor dQ/dt which is the inclination of the straight line depends on geometric factors which are the shape, the precision of machining and the surface state of the petrol flow conduits around the tip of the needle, particularly the quality of the seating.

Methods of machining are already known which enable a good linearity of the rate of flow dQ/dt to be obtained during the whole stroke of the tip and a weak dispersion of the variations on the value of the inclination dQ dt measured on batches of mass-produced injectors.

French Patent No. 76 02334 describes a method for manufacturing needle seatings by electrolytic machining then by stamping by means of stamps which leads to a good reproducibility of the measurements of instantaneous rate of flow on batches of injectors.

It is a first object of the present invention to improve the methods for manufacturing and machining the electromagnetic injectors to render them more economical, particularly by eliminating electrolytic machining.

The second factor to is the ordinate at the origin of the straight line. It is the time constant separating the beginning of a pulse from the opening of the needle. This time constant essentially depends on the inertia of the needle and the uniformity of the stroke of the needle on all the injectos, i.e. on the precision of adjustment of the air gap which separates the end of the needle when it is closed from the non-magnetic stop against which it abuts at the end of stroke.

It is another object of the present invention to procure means for adjusting the width of the air gap with a very high precision during mass-production and to correct it, if need be, after manufacture.

The electromagntic injectors forming the subject matter of the invention comprise, in known manner, a hollow body, an electro-magnet coil located in said body and an injection needle, of which a first end is in the form of a conical tip which is supported by a calibrated spring on a seating which is fast with said body and which is extended, above the bearing surface of the needle, by a chamber of revolution about the axis of the needle, whose outer diameter is greater than the outer diameter of the needle.

The objects of the invention are attained by means of an injector in which the hollow body comprises three coaxial pieces:

- a first base piece which bears the seating at one end which contains said needle and a ring for guiding said latter and which comprises at the end opposite the seating, a flange;
- a second piece which is a tube bearing a flange at one end;
- a spacer ring interposed between the two flanges,

which three pieces are assembled together by a crimping envelope.

The invention also relates to the methods for manufacturing an injector according to the invention. These methods comprise the following operations:

- machining a blind bore in the first base piece of the body and piercing a calibrated orifice at the further end thereof;
- forming the walls of the seat by stamping the end of said bore by means of stamps;
- placing the needle and the ring for guiding same in the first part of the body, the needle resting on its seating;
- and assembling the three parts of the body together by means of a crimping ring.

The needle of an injector according to the invention bears, in known manner, at the end opposite the tip, a pole face and when the needle is closed, the pole face is separated by an air gap from the end of an end piece provided with a flange which comes into abutment on the free end of the body.

The methods for manufacturing the injectors having an air gap of well determined width comprise the following operations:

- the tip of the needle being applied on the seating, the distance Z between the free face of the pole face and the free end of said body is measured with very high precision, of the order of a micron;
- the length Y of the calibrated spring intended for said injector when said spring is subjected to a well determined load which is the same for all the injectors and which is substantially equal to the load of the springs in place, is measured with a very high precision;
- the terminal face of said end piece is machined with precision so that the distance separating said

face from the support face of said flange carried by the end piece is equal to Z − e, e being the desired air gap width;

- the shoulder on which the end of said spring abuts is machined with precision on said endpiece, so that the distance from this shoulder to the machined end is equal to Y.

The invention results in novel electromagnetic injectors and the possibility of mass producing them for an acceptable cost, obtaining a constant ratio between the quantity of fuel injected and the injection time with a dispersion of the results from one injector to another lower than ±1%, thus making it possible to comply with the requirements of legislations concerning pollution control.

The constitution in two pieces of the part of the body of the injector which surounds the injection needle, i.e. an outer body and a ring for guiding the needle, makes it possible to machine the seating and the chamber which extends it without having to resort to electrolytic machining. Final machining may be effected solely by stamping by means of stamps, without removal of cuttings, this enabling a good surface state to be obtained.

The calibrated base body which does not form part of the magnetic circuit may also be moulded from a heat-setting resin.

The method of manufacture according to the invention makes it possible, by precision machining of the end piece, to obtain an airgap e and a load of the calibrated spring which are identical for all the injectors of the same series. The constancy of the air gap brings about the constancy of the magnetomotive return force of the injection needle and the constancy of the stroke thereof.

The masses of all the needles being constant, the same constancy of opening time of the tip is obtained for all the injectors.

Moreover, if checks after manufacture show that certain injectors have a constancy of opening time beyond the admissible range, it is possible to remedy this variation whatever its direction.

The invention will be more readily understood on reading the following description with reference to the accompanying drawings, in which:

Figure 1 is an axial half-section through an injector

Figure 2 is an axial section and *Figure 3* a transverse section through the ring for guiding the injection needle.

Figures 4 and *5* are axial sections through a blank of the base piece of the body of the injector.

Figure 6 is an axial section through the seating of the injector and the chamber surmounting same.

Figure 7 is a diagram showing the variations in the quantity of fu l Q as a function of the duration of pulses Δt.

Figures 8 to *10* are schematic representations of the final stages of manufacture and control of the injectors according to the invention.

Referring now to th drawings, Figure 1 shows an electromagnetic injector, for example an injector intended for injecting p trol or gasoline in a heat engine under the control of an electronic device which sends voltage pulses on the coil of the injector and which varies the duration of said pulses as a function of th running of the engine and the power required.

This injector comprises a hollow body composed of three coaxial pieces.

The first base piece 1 bears a convergent seating 2 which is extended forwardly by a calibrated orifice 3. This base piece comprises a flange 4 at the end opposite the seating.

The second piece 5 is in the form of a tube which bears a flange 6 at one end.

The third piece 7 is a spacer ring interposed between the two flanges. O-rings 8, housed in grooves, ensure the tightness between these three pieces. The three pieces are assembled toether by a crimping envelope 9.

The injector comprises an electromagnet coil 10 which is placed around the tube 5 and which is suplied by two leads 10a and 10b. It comprises an injection needle 11, one end of which is in the form of a tip 12 which cooperates with the seat 2. The end of the needle opposite the tip bears a pole face 13 which forms part of the magnetic circuit. The injector further comprises an endpiece 14 provided with a flange 15 which abuts on the free end of the piece 5 of the body. This endpiece 14 is pierced with a fu l inlet channel 16 in which a filter 17 is placed. The end of the endpiece is connected to a fluid inlet pipe (not shown).

The endpiece 14 comprises an extension 14a which penetrates inside the tube 5 and the lower end of this extension bears a non-magnetic stop 18, of small section, intended for avoiding the pole face adhering to the magnetic circuit. This stop is made of a hard material in order that the high operational frequency does not alter the value of the stroke e of the needle equal to the width e of the air gap 23 which separates the top of the needle from the stop when the tip is closed. The width e is determined with very high precision when each injector is manufactured and it must remain virtually constant during the whole life of an injector.

An O-ring 19 housed in a groove ensures the tightness between the body 5 and the endpiece 14. The tip 12 is maintained in abutment on its seating by a calibrated spring 20 which abuts on the one hand on a shoulder of the pole face and on the other hand on a shoulder 21 of the piece 14a. The body of the injector and the endpiece 14 are assembled by a crimped envelope 22 which surrounds the coil and which is made of a ferromagnetic material, with the result that it channels the magnetic field. The magnetic circuit passes through the envelope 22, the flange 15, the piece 14a, the air gap 23, the pole face 13, the spacer ring 7 and the envelope 9.

The injector further comprises a cavity 24 in which the calibrated orifice 3 op ns. This cavity comprises a vent 25 which serves to cause a preliminary oxidation of the jet of fuel. The cavity 24 may receive a diffuser endpiece 26 pierced with one or more channels 27 oriented as required. The endpiece 26 has been shown out of the cavity 24 for greater clarity of the drawing.

The functioning of this type of injector is well known. When the coil 10 receives a voltage pulse, the needle is lifted by the magnetic attraction and a

quantity Q of fuel flows through the calibrated orifice 3. This quantity of fuel is a function of the duration Δt of the pulse and depends on the geometrical characteristics of the fuel circuit.

The geometrical characteristics may be varied by simply replacing the base piece 1 by a piece having a different calibrated orifice. A range of injectors may thus be obtained whose rates of flow vary between 3 mm^3 and 15 mm^3 per millisecond.

It is known to obtain voltage pulses electronically with a very high precision greater than one thousandth of a second.

It is desired to mass-produce, for a relatively moderate cost, injectors in which the hydraulic and mechanical factors which influence the rate of flow are obtained with a precision comparable to that of the duration of the pulses.

A rate of flow characteristic $Q = f(t)$ must be obtained which is linear as a function of time, and a very weak dispersion lower than $\pm 1\%$ of this characteristic, on mass-produced batches of injectors.

The quantity Q of fuel delivered during each pulse of duration Δt must be of the form $Q = dQ/(dt)\ (\Delta t - to)$ which is the equation of a straght line of inclination dQ/dt (instantaneous rate of flow) passing through an origin to. to represents the time constant of the needle, i.e. the time which separates the beginning of a voltage pulse from the detachment of the tip.

The inclination dQ/(dt) is of shape $\mu.S.\sqrt{\Delta P}$, in which formula ΔP represents the difference in pressure on either side of the calibrated orifice 3, S is the section of the calibrated orifice and μ is a geometrical factor which depends on the shape and surface state of the seating 2.

The injector comprises, in known manner, upstream of the seating 2, a chamber 28 which is of revolution about axis z zl of the injector. This chamber, whose walls extend those of the seating 2, has an outer diameter larger than the outer diameter of the needle, so that it forms a reserve of fuel under pressure and the value of ΔP remains constant for the whole duration of the pulses. The chamber 28 is supplied with fuel via channel 29.

French Patent No. 76 02334 describes a method for manufacturing the chamber 28 and the seating 2 by electrolytic machining followed by stamping of the seating by means of stamps. The electrolytic machining enables a very good surface state to be obtained, but it is a relatively complex operation.

The injectors according to the present invention are designed to achieve the same result but without resorting to electrolytic machining.

To this end, the base piece 1 of the body comprises, about the needle, a blind axial bore 30, shown in Figure 4, whose diameter is clearly larger than the outer diameter of the needle and substantially equal to the largest diameter of the chamber 28. The injector further comprises, inside the bore 30, a ring 31 for guiding the needle 11, which is shown in Figures 2 and 3.

The ring 31 has an outer diameter equal to the diameter of the bore 30 and is engaged therein. The ring 31 comprises an axial bore 32 having a diameter slightly larger than the outer diameter of the needle 11 which slides freely in the bore 32. The ring 31 comprises on its periphery one or more grooves 29 which serve as fuel inlet conduits in the chamber 28. The lower end 33 of the ring 31, i.e. the end located on the seating side, is concave in form, so that the outer edges of the concavity extend the walls of the chamber 28 and are tangentially connected thereto as shown in Figure 6.

Figures 4, 5 and 6 show successive steps of the method according to the invention for manufacturing base pieces 1.

In a first step shown in Figure 4, a blank is made by machining in a bar 1 a cylindrical cavity 24, a blind axial bore 30 and a flange 4. The bore 30 is machined to a definitive nominal diameter. The end of the bore is extended by a conical point 34 having an angle of the order of 90°.

Figure 5 shows the following step in which a tip 35 is machined having an angle of the order of 15°, and the calibrated orifice 3 which is machined with a very high precision. The orifice 3 is firstly pierced with a diameter slightly smaller than the nominal dimensions, for example with a variation of 0.01 mm, then the walls are surfaced by passing a rod through the orifice 3 which takes it to the definitive dimensions.

Figure 6 shows the following step on a larger scale. The left half of the Figure shows the end of the bore 30 with the two conical sections 34 and 35 and the calibrated orifice 3. The right half shows the finished seating 2 on the pressure chamber 28 and the ring 31 engaged in the bore.

This Figure shows the concave shape of the end 33 of the ring 31 whose edges are tangentially connected to the edges of the cavity 28.

To obtain the continuous surface of the seating 2 in the form of a converging funnel from the conical points 34 and 35, the metal is stamped by means of a stamp 36 whose tip takes the final form of the seating which it is desired to obtain.

This final form, visible on the right half of Figure 6, comprises an upper part 28a in the form of a semi-torus which is tangentially connected on the one hand to the concavity 33 and on the other hand to the 90° cone 28b. The cone 28b is downwardly extended by a cone 28c having an angle of about 15° which is tangentially connected on the one hand to the cone 18a and on the other hand to the calibrated orifice 3.

The progressive connections between cones are obtained by crushing the connecting edges by means of the punch. A continuous, perfectly surfaced, reproducible surface is thus obtained from one injector to another and the geometrical characteristics of the mass-produced injectors present few variations.

As a variant, the pieces of the body 1 and 5 which do not form part of the magnetic circuit may be made by moulding heat-setting resin and, in this case, the walls of the seating are rough-cast and present a good surface state.

It has been seen hereinabove that it is sought to inject, during each pulse of duration Δt a quantity Q of fuel which is of the form $Q = dQ/(dt)\ (\Delta t - to)$, to being a time constant which determines the origin of the straight line representing the above equation.

Figure 7 shows on the x-axis the time t and on the y-axis the quantity of fuel Q. This Figure shows two straight lines D and D' having the same inclination but of different origins to and t'o. The origin of the time corresponds to the origin of the voltage pulses. It is seen that for the same pulse duration Δt, the variation ΔQ due to a variation Δto of the value of the time constant to is considerable and this variation ΔQ is proportional to the value of the inclination dQ/dt. It is not possible to eliminate the time constant to. It may be reduced by reducing the mass of the mobile assembly to a maximum.

The essential is therefore to obtain the same time constant to for all the mass-produced injectors, to be able to check that the variations remain within very narrow limits and to be able to correct if need be. The value of the time constant to depends on the one hand on the reluctance of the magnetic circuit which is to a large extent determined by the width of the air gap 23 and on the other hand on the load of the calibrated spring when the needle is closed.

It is an object of the present invention to provide methods for manufacturing injectors which make it possible, in combination with the structure of these injectors, to manufacture series of injectors having air gap widths e presenting very slight variations from one injector to another,

An important element is the length of the return spring 20 under a load equal to the calibration of this spring. It is not known to manufacture series of springs economically whose length under a determined load does not present variations.

Usually, when injectors are mass-produced, a distance is determined between the two shoulders on which the two ends of the spring 20 abut, equal to the mean value of the length of the calibrated spring when it is under normal load, for example a load of the order of 100 g. This results in the effective load of the springs in position varying around this mean value and as the load is an important factor for determining the time constant to, there are considerable variations on the value of to for injectors of the same batch even if the width e of the air gap is constant.

According to the invention, the endpiece 14, 14a and particularly the end thereof which serves as stop for the pole face 13 and the shoulder 21 against which the calibrated spring 20 abuts, are machined with a very high precision. This machining is made with respect to a reference surface which is the support face of the flange 15 against the free end of the body 5.

Figures 8 to 10 show the successive steps of the method.

Figure 8 shows the first step. The three pieces 1, 5 and 7 of the body are definitively assembled by the crimped envelope 9 and the needle 11 is engaged in the guide ring 31, the tip 12 resting on the seating 2.

The distance Z between the top of the pole face 13 and the free end of the piece 5 is measured by means of a comparator 37, with a very high precision, of the order of a micron.

In a second step, the spring intended for the injector of which dimension Z has been measured is placed under a determined load, constant for all the springs, for example a load of 100 g which is the load in place, which the calibrated spring must exert on the needle when the latter is closed and in abutment on its seating.

The length Y of the spring under this load is measured with the comparator.

Figure 9 shows the third step of the method which is the machining of the endpiece 14, 14a.

The terminal face 38 of the end piece 14a and/or of the non-magnetic stop 18 carried by this endpiece, is firstly machined, so that the distance which separates this face from the support face of the flange 15 is equal to z − e, e being the very small width of the airgap 23 which it is desired to obtain. It is checked with the aid of a comparator 39 that the desired dimension has been obtained with high precision.

The shoulder 21 on which the spring 20 must abut is then machined, so that the distance separating said spring from the end 38 is equal to the dimension Y measured previously.

These machining operations may be conducted automatically by a digitally controlled machine tool which has memorized the constant value e and which records the measurements of Z and of Y.

Once this machining is terminated, the trial assembly of Figure 10 is effected, in which the calibrated spring, the endpiece 14, 14a and the coil 10 are placed in position in the pre-assembled sub-assembly according to Figure 8. The whole is enlcosed between two metal covers 40 and 41 which slide telescopically in each other and which close the magnetic circuit. This sub-assembly is placed on a fixed frame 42 comprising a plate 43 pierced with an orifice and a bracket 44 in which is screwed a screw 45 which abuts on a plastic cap 46 abutting on the upper cover 41 and which holds the flange 15 of the endpiece against the upper end of the body. An accelerometer 47 abuts against the cover 41, a pulse is sent into the coil 10 and the time interval tl is measured which separates the beginning of the pulse from the signal delivered by the accelerometer which corresponds to the shock of the pole face against the stop.

The measured value tl is compared with the constant to which it was desired to obtain. If the difference tl − to is greater than the maximum variation acceptable, the sub-assembly is dismantled and correction is effected by remachining the endpiece 14, 14a. If tl is too great, the air gap e is too wide. Correction is effected by altering the suport face of the flange 15. If, on the contrary, tl is much smaller than to, the airgap e is too small. Correction is effected by altering the terminal face of the endpiece 14a and the shoulder 21.

In general, it is not necessary to alter after the first machining of the endpiece 14, 14a, as this machining is made with precision after the dimension Z on a definitively assembled sub-assembly and the length Y of the particular spring intended for each injector have been measured with very high precision.

This method differs from presently used methods where all the pieces are machined with high precision and are then assembled, this leading to a dispersion. To remedy this, the injectors are then checked one by one, on a dynamics testing bench,

and the return spring is adjusted to compensate the variations. This control means is long and expensive and the variations obtained after control remain of the order of ±3%, whilst the method according to the invention makes it possible to obtain variations in the rate of flow characteristic of all the injectors of the same batch of less than ±1% with a less complicated control.

CLAIMS

1. An electromagnetic injector intended for injecting a combustible fluid in a heat engine, comprising a hollow body, an electromagnet coil located in said body and an injection needle of which a first end is in the form of a conical tip which abuts by a calibrated spring on a seating, wherein said hollow body comprises three coaxial pieces:
- a first base piece which bears the seating at one end, which contains said needle and a ring for guiding said needle and which comprises a flange at the end opposite the seating;
- a second piece which is a tube bearing a flange at one end;
- a spacer ring interposed between the two flanges;

which three pieces are assembled together by a crimping envelope.

2. A method for manufacturing an injector as claimed in Claim 1, comprising the following steps of:
- machining a blind bore in the first base piece of the body and piercing at the end thereof a calibrated orifice;
- forming the walls of the seating by stamping the end of said bore by means of stamps;
- placing the needle and the ring guiding same in the first part of the body, the needle resting on its seating;
- and assembling the three parts of the body together by means of a crimping ring.

3. A method of manufacture as claimed in Claim 2 of an injector whose injection needle bears at its end oposite the tip a pole face, which is separated by an airgap, when the needle is closed, from the end of an endpiece provided with a flange which abuts on the free end of said body of the injector, comprising the following steps of:
- measuring with very high precision, of the order of a micron, the distance Z between the free face of said pole face and the free end of said body, the tip of the needle being applied on the seating;
- measuring with very high precision the length Y of the calibrated spring intended for said injector when said spring is subjected to a determined load which is the same for all the injectors and which is substantially equal to the load of the springs in place;
- machining with precision the terminal face of said end piece, so that the distance separating it from the support face of said flange carried by the endpiece is equal to Z − e, e being the desired airgap width;
- precision-machining on said endpiece the shoulder on which abuts the end of said spring, so that the distance from said shoulder to the machined end is equal to Y.

4. A method as claimed in Claim 3 for checking and correcting the airgap width, comprising the following steps of
- placing an accelerometer in contact with the injector which detects the impact of the pole face against its stop;
- measuring the time interval tl which separates the beginning of a voltage pulse from the impact that it produces;
- comparing with a reference value to and, if there is a difference greater than the maximum variation admissible, altering either the terminal face of the endpiece if the time interval is too short, or the support face of the flange of the endpiece if the time interval is too great.

5. An injector as claimed in Claim 1, wherein said base piece defines a chamber of revolution which surrounds said tip and in which said ring for guiding the needle comprises, on its outer periphery, at least one longitudinal groove which extends over the whole height of said ring, which opens out in said chamber and which serves as inlet conduit for the combustible fluid in said chamber.

6. An injector as claimed in Claim 5, wherein the end of said guide ring which is located on the seating side, in said chamber presents a concave shape, which extends the walls of said chamber.

7. An electromagnetic injector substantially as described hereinabove and illustrated in the accompanying drawings.

8. A method of manufacture substantially as described hereinabove and illustrated in the accompanying drawings.

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